5. RECOVERY HYPOTHESES

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We have developed recovery hypotheses to express our conclusions about the key factors and uncertainties that affect the viability of salmon and bull trout through their interactions with nearshore and marine environments of Puget Sound. [1] These hypotheses synthesize the material presented in sections 2 through 4 and, hence, are based on a significant body of knowledge.

Many of these hypotheses guide the evaluation of marine sub-basins of Puget Sound that we present in Section 6. These hypotheses, and the results of the sub-basin evaluations, provide the basis for the recovery strategies presented in Section 7.

In addition to a succinct statement of our hypotheses, we also discuss the basis (e.g., empirical studies in the region, empirical studies from elsewhere, conceptual understandings) for the hypotheses and our evaluation of the certainty and risks involved in each of these statements. For some hypotheses we also provide an elaboration of the simple hypotheses statement.

5.1 Hypotheses about nearshore and marine processes and habitats

1. Movement of sediment, water, and organic matter and ecological interactions (e.g., nutrient cycling, trophic transfers, and community succession) are the key ecosystem processes at the regional scale of analysis

   Basis: Conceptual discussions by Goetz et al. (2004), Simenstad (2000), and Bauer and Ralph (1999) offer distinct but consistent arguments for addressing this suite of processes in restoration and assessment. Simenstad (personal communication with K. Fresh), Beechie et al. (2003) and Bauer and Ralph (1999) describe hierarchical interactions of processes at this scale with processes operating at different scales.

   Certainty: Moderate. Conceptual basis introduces some uncertainty (i.e., this hypothesis has not been tested and may not be testable) but various authors are in general agreement.

[1] Although we have not organized our presentation in this way, we have developed hypotheses to address the two types of questions suggested in parts A and B of Section 3.3.2.1 of the TRT's guidance for integrated recovery planning (TRT & Shared Strategy Staff Group, 2003). These questions, interpreted for application to nearshore and marine environments, ask about:

- Effects of Puget Sound nearshore and marine ecosystems on the demographic, genetic, and ecological processes that determine the current and future viability of salmon and bull trout populations; and
- Mechanisms through which habitat management actions affect habitat-forming processes and the conditions of nearshore and marine ecosystems and the functions of these ecosystems for salmon and bull trout.

Risks: Adopting this hypothesis risks neglect of other potentially important processes such as climate variation and volcanism (which operate at larger scales) and biogeochemical processing across benthic-pelagic systems (which operates at smaller scales). Large-scale processes such as climate variation and catastrophic changes, to the degree they are addressed as part of the overall approach in the regional recovery plan, will reduce the risks here. This hypothesis is fundamental to our approach to the chapter (as discussed in Section 2.1) and likely limits the scope of other hypotheses and the focus of subsequent strategies and actions.

2. Spatial and temporal variations in landscape processes create a dynamic mosaic of conditions in nearshore and marine ecosystems.

   Basis: Shipman et. al (in prep) cites evidence of variation in many types of geomorphologic processes (e.g., exposure, tidal range) directly from Puget Sound shorelines. Beechie et al. (2003) assert that "spatial and temporal variations in landscape processes create a dynamic mosaic of habitat condition in a river network" (and cite two works as examples that support this assertion).

   Certainty: High. Direct evidence from Puget Sound shorelines suggests very little uncertainty in this hypothesis. Beechie et al. (2003) make the assertion cited above as one of two factors that provide the scientific basis for their approach to recovery assessments.

   Risks: Adopting this hypothesis introduces little risk to our assessments and conclusions. This hypothesis may lead us to a more detailed analytical approach than would be necessary if processes operate uniformly over the Puget Sound landscape.

5.2 Hypotheses about effects of nearshore and marine environments on salmon

We offer the following hypotheses about how nearshore and marine environments can directly and significantly affect the viability of salmon and bull trout. Inherent in the statements below is the assumption that nearshore and marine environments can affect various units of salmon organization: individual fish, various life history strategies, populations, and ESUs or DPSs.

3. Use of nearshore and marine habitats by salmon and bull trout depends on species, life history type, and fish size

   Basis: Section 3c describes differences across species (with citations to Healy 1982 and Simenstad et al. 1982), populations (with citations to "a wide body of literature that demonstrates that habitat use depends on population of origin"), and life history strategy (with citations for Chinook to "a considerable number of studies"). The discussion in Sections 3c and 3e also addresses differences in habitat use by Chinook of different sizes.

Certainty: High. There is a considerable body of work (cited in Section 3) that informs this hypothesis.

Risks: Adopting this hypothesis introduces little risk to our assessments and conclusions. This hypothesis may lead us to a more detailed analytical approach than would be necessary if habitat use did not vary across space and time by species, populations, etc.

4. Viability of salmon ESUs and anadromous portions of bull trout DPSs demands natal estuaries, nearshore areas adjacent to natal estuaries, and a diversity and connectivity of more distant nearshore habitats to provide food, refuge, conditions to support physiological transition, and functional migratory corridors.

4.1 Natal estuaries are especially important for Chinook of the delta fry life history type but must function for all salmon and anadromous bull trout.
4.2 Nearshore areas adjacent to natal estuaries are especially important to small, weakly swimming fish, such as Chinook of the fry migrant life history type and outmigrant chum, but must also support larger fish.

Basis: Simenstad et al. (1982) and Simenstad and Cordell (2000) introduce the concept of four functions for salmon in nearshore environments. Section 3e offers considerable detail, including empirical evidence, about how various life histories and species use natal and non-natal estuaries and other nearshore and marine environments. The significant contributions of estuarine reared life history types to adult returns as documented in Riemers (1973) and Hayman et. al. (1996) is discussed in further detail in Section 3. Simenstad (2000) and Simenstad (2000a) argue conceptually for the importance of connectivity of habitat elements. Beechie et al. (2003) argue from the (conceptual) scientific basis of their approach to recovery that "salmonid species or populations are adapted to spatially and temporally variable habitats [and that] environmental variability is important to the long-term survival of populations." The argument that population viability specifically demands fully functioning natal estuaries and adjacent nearshore environments and moderately intact and functional distal nearshore environments is developed as a synthesis of the material presented in Section 3 of this document.

Certainty: Moderate. There is a considerable body of work (cited above and in Section 3) that informs and supports some elements of this hypothesis. However, the overall hypothesis is relatively less certain because the empirical evidence, or directly applicable conceptual discussion in the literature, about the specific relationships between population viability and conditions of various elements of the nearshore and marine landscape has not yet been as well developed as those for freshwater landscapes.

Risks: Adopting this hypothesis, and using it to define strategies and actions, risks misdirection of attention and resources from habitats that might later be shown to better contribute to salmon and bull trout viability. For example, future model results might indicate that Chinook ESU viability is substantially affected by nearshore resources very distant from natal estuaries (e.g., in Admiralty Inlet) or is not measurably affected by large changes in nearshore conditions.

5. Viability of the Puget Sound Chinook ESU demands functioning nearshore and marine habitats in all sub-basins (to maintain or enhance nearshore and marine aspects of population and ESU spatial structure) and a distribution of functions within sub-basins to support expression of each of the four outmigrant life history types in each of the five geographic regions of diversity and correlated risks.

   Basis: This hypothesis derives from a conceptual argument, with a building basis in direct empirical evidence of the distribution of marked juvenile salmon in various Puget Sound locations, developed in Section 3 of this document. This evidence verifies a large body of indirect evidence for juvenile and sub-adult distribution throughout Puget Sound locations based upon various fishery contribution information (e.g., co-manager Chinook Technical Committee reports on stocks status). This hypothesis is a regional nearshore and marine application of the NOAA Fishery concepts of spatial structure and diversity as key elements of population and ESU viability. For further details on the conceptual basis for how ecological conditions and processes relate to ESU persistence can be found in Mc Elhaney et. al. (2000), Beechie et al. (2002), Waples et al. (2001), Willamette and Lower Columbia River Viability Criteria (WLC TRT, 2003), Fresh (In prep), and in the Puget Sound TRT Nearshore Recovery Planning Guidance (2003). Conversely, an alternative hypothesis that has been widely held, that the nearshore serves only as a seasonal transportation corridor for juvenile Chinook with unlimited capacity and little potential to influence population performance, was based upon limited and narrower information base that is no longer supported by the weight of evidence over a broader range of disciplines as suggested above.

   Certainty: Moderate. The significance of nearshore and marine environments to various expressions of population spatial structure and outmigration life history types contributions to viability of salmon populations and ESUs is conceptually straightforward but the specifics of relationships among nearshore habitat processes, conditions, and population responses, at scales relevant to habitat protection and restoration strategies and actions, are not yet well addressed in the literature.

   Risks: Adopting this hypothesis, and using it to define strategies and actions, risks misdirection of attention and resources from types of spatial structure and life history diversity that might have greater effects on Chinook salmon viability. For example, future model results might indicate that Chinook ESU viability is (a) affected by spatial diversity of spawning locations but not (significantly) affected by the spatial distribution of areas supporting nearshore rearing or (b) not responsive to efforts to maintain or enhance parr and yearling migrant survival in a given sub-basin. On the other hand, not adopting and testing this hypothesis could readily lead to misplaced confidence that actions taken in freshwater areas are most effective and sufficient to achieve recovery goals.

6. Realized function, which combines an assessment of opportunity and capacity, can be used as a synthetic measure of a landscape's support for salmon and bull trout populations

   Basis: The application of stock recruitment functions has been one of the most intensively studied subjects in fisheries management over the past fifty years. Early applications focused mostly on full life cycle modeling [spawner/recruit curves] for harvest management applications. However, the capabilities of stock recruitment function modeling of life stage performance at time/space increments relevant to habitat management actions has been well developed in recent years. In addition, Simenstad (2000) and Simenstad and Cordell (2000) have introduced the concept of realized function as the product of opportunity and capacity and apply landscape ecology principles such as connectivity to link fine habitat scales and organism level responses to landscapes and population levels. The combination of landscape ecology and stock recruitment tools presents a robust framework for investigations into the support various landscapes provide to salmon and bull trout populations.

   Certainty: Moderate. This hypothesis is somewhat uncertain because the empirical evidence and discussion in the literature has limited applications at scales that can serve to inform the responses of the four life history types to nearshore habitat conditions and thereby the relationships among nearshore habitat processes, conditions, and population responses relevant to habitat protection and restoration actions.

   Risks: Adopting this hypothesis introduces little risk to our assessments and conclusions. One possible risk is that reliance on the assessments of opportunity and capacity could lead us to neglect some of the specific functions. However, this risk seems remote since other hypotheses and our analytical approach retain some attention to four functions of nearshore and marine habitats for salmon and bull trout.

5.3 Hypotheses about human interactions with nearshore and marine ecosystems as an influence on the viability of salmon and bull trout

7. Stressors affect four functions for juvenile salmon; the effects of these stressors vary by location and by stressor

   Basis: Sections 4.2 to 4.8 include discussion of (a) the effects of individual stressors on nearshore and marine habitat functions for salmon (with numerous citations to empirical evidence and/or conceptual arguments) and (b) the general distribution of each stressor across the Puget Sound landscape (with citations to others' characterizations of the various stressors).

Certainty: Moderate. The nature of effects of stressors on functions for salmon is fairly well substantiated. Quantitative relationships between stressors and functions (or stressors and population or ESU viability) are not developed.

Risks: Adopting this hypothesis introduces little risk to our assessments and conclusions. This hypothesis may lead us to a more detailed analytical approach than would be necessary if effects of stressors were uniform or if their distribution across the Puget Sound landscape were uniform.

8. <u>Protection and restoration of nearshore and marine ecosystems to maintain or enhance realized function should address underlying ecosystem processes</u>

Basis: Conceptual argument developed by Puget Sound TRT and Shared Strategy Staff Group (2003). (See especially Box 2 and accompanying text in the TRT Technical Guidance for Watershed Groups.)

Certainty: High.

Risks: Adopting this hypothesis is intended to reduce uncertainty in recovery and does not introduce significant risks to our assessments or conclusions. However, because process-based restoration and protection are not well established in all management regimes and may not be well understood by sponsoring organizations, process-based actions and strategies might be questioned as indirect solutions to the specific problems confronting salmon and bull trout.